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SCALING BETWEEN LEAF AND LANDSCAPE  
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## Workshop on "Ecological Scaling Between Leaf and Landscape Levels"

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A workshop on developing and evaluating tools and approaches for scaling ecological processes between leaf and landscape levels was held at Snowbird, Utah on December 2-5, 1990. The focus of the workshop was on terrestrial ecosystems and on the paradigms and approaches that will be productive to address questions of scale. Integrated within these discussions was the application of such approaches to emerging questions of climate change and our ability to predict ecological responses to perturbations. Thirty-five environmental scientists participated in the workshop, spanning the range of specializations from remote sensing through ecosystem studies and microclimatology to biochemistry and physiology. The group was a blend of theoretical and experimental investigators and consisted of both established and young investigators (participants list attached). The format of the workshop was sets of individual presentations through the morning addressing particular scaling issues, followed by small group discussions in the late afternoon and again in the evening (meeting schedule attached). Several hours were left open at midday to allow for individual discussions. By bringing together investigators interested in scaling issues, but many of whom might not normally interact with each other because of discipline differences, we achieved a lively and productive set of discussions and spawned new sets of interactions that, hopefully, will continue to be productive in the future.

The workshop focused on five main issues:

**What productive theoretical and conceptual approaches are there for addressing questions of scale in ecology?** This was an extremely interesting session to start the workshop off. Theoretical aspects of pattern analysis, mathematical aspects of defining scaling boundaries, modeling approaches, and the role of key mechanistic processes in influencing ecosystem dynamics dominated the discussions in this session. Interestingly, "chaos" and "hierarchical" approaches to ecological scaling received relatively little attention, despite the fact that several of the participants were familiar with these approaches.

**What are the prospects that "bottom-up modeling" will provide the insights necessary for scaling at the next higher level of interest?**

Mechanistic modeling of mass and energy transfer has a long history in ecology, but what impact can complex, detailed models have on our understanding at the ecosystem and regional levels? Here the emerging viewpoint was that detailed mechanistic models at the process level have limited impact on improving our understanding more than one level up, in part because some of the detail is apparently not necessary, but more likely because few characteristics are simple

enough to have their effects penetrate through several layers without modification. Also many of the physiological interactions are "averaged" having less impact at higher levels of interest. The need for simultaneous construction and testing of both mechanistic, process-level models and less detailed ecosystem models was stressed, as it was felt that only by comparative evaluation would we see which physiological parameters could be eliminated and which useful as ecosystem and landscape level models are developed.

**What perspectives can "ecophysiology", which addresses questions of mechanisms, contribute to ecosystem and landscape level studies?**

Incorporation of physiological processes has a critical impact in bringing greater reality and precision to ecosystem and landscape level models. That organisms are sufficiently different and complex brings both excitement and frustration to our efforts in ecological scaling. Yet extraction of the essential physiological components and identification of those physiological characters or processes that are scalable is essential. Half of the discussion here revolved around what physiological characteristics provide the necessary parameters to describe mass and energy transfer at the canopy levels and in general circulation models. Such efforts have only been fruitful when individuals from ecophysiological, climatological, and landscape levels collaborate in team efforts, which need to be encouraged with financial support though not at the expense of support for single investigator projects. The remaining half of the discussion revolved around the temporal and spatial insights at both the global and regional levels that are now emerging from stable isotopic analysis. This was a particularly exciting set of discussions as climatologists and ecophysilogists with different backgrounds but common interests discussed the mechanistic basis for isotopic fractionation on one hand and the impact of the fractionation processes in understanding larger-scale issues such as the global carbon budget on the other hand.

**To what extent, can different species be melded into functional groups and population-level phenomena ignored in considering ecosystem responses?** Scaling from one level to another requires organizing the complexity at the lower level. Much discussion was spent on the potential for functional groupings of species. While it is easy to conclude that each situation is ecosystem-specific, participants stated that functional responses of different species to most stresses were sufficiently similar that functional group concepts were appropriate for a large number of situations. The distinction between approaching ecosystem level phenomena and responses on the "per square meter" versus the "individual" basis was more challenging. Ecosystem and landscape ecologists have typically addressed their studies with the "per square meter" approach. This approach is easily scalable when utilizing remote sensing methods and apropos for many flux measurements. Yet strong theoretical and experimental arguments were presented for the role of individuals in understanding and predicting ecosystem-level responses to environmental perturbation and of the possible consequences to long-term ecosystem dynamics when population-level phenomenon are ignored.

**What influence is technology having on our understanding of questions of scale in ecology?** Stable isotopes, geographical information systems, remote sensing, and instrumentation for assessing mass and energy fluxes across canopy and regional boundaries have had a tremendous impact on ecology in the past decade. The consensus was that the state of these technologies was not the limiting factor in progress, although access to these technologies and training scientists in their application continue to be major limitations. The capabilities of these technologies for spatial and temporal integration of ecological processes were deemed outstanding. Until sufficient data sets are available, however, the data base from which to extrapolate is far too limited. Additionally, more cross fertilization of students and young scientists trained in a hybrid fashion so as to link ecological studies with these technologies (that are still largely based in physics and climatological domains) is critical.

Other workshops on aspects of ecological scaling, global climate change, and modeling have of course been held over the past several years. Many of our participants had also participated in one or more of those meetings. It was gratifying to hear that these individuals felt that the Snowbird workshop was more productive in bringing these issues to the forefront, addressing them in a more lively and constructive way, and more likely to result in a product that will have a beneficial impact on the field.

The product of this workshop is a book to be published by Academic Press titled "Scaling Physiological Processes: Leaf to Globe".

Note: There were no patents or inventions associated with this grant.